# Dynamic Processes of Scientific Collaboration: The Evolution of the U.S. University Inventor

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## Abstract
This study examines U.S. university inventors as dynamic actors in the evolution of scientific research collaboration. At the epicenter of the real world processes that translate university research into usable technologies, university inventors play an important role in shaping the complex system of scientific innovation. As ongoing deliberations propose to change national intellectual property policies, the growing complexity of university inventor collaborations have on the system of innovation must be reckoned with. These collaboration networks have evolved dynamically since important policy changes were made to the laws and structures governing intellectual policy protection, university technology transfer, and intellectual property enforcement during the 1980's. The purpose of this study is to examine the dynamic processes of knowledge diffusion by analyzing community structure from relevant evidence that knowledge exchange is occurring: the intellectual property jointly developed and owned by inventors and institutions in the form of a patent.

## Research Questions
Providing a focal point to interpret the Bayh-Dole Act of 1980, this study asks: 1) how have patterns of scientific collaboration on patents granted to U.S. universities changed over the last thirty years? 2) Is there evidence that university collaboration on patents increases technology impact as measured by citation strength? 3) Is there evidence that knowledge diffusion is enhanced by collaboration on patents granted to U.S. universities?

## Data and Method
Methodologically grounded in network analysis, scientometrics, and visualization science, this study uses multiple methods on multiple data sources to explore U.S. university inventor networks. For this study, inventor networks are derived from the U.S. Patent and Trademark Office's [USPTO] PATSIC, CONAME and INVENTOR data files containing information on patents that were granted to U.S. universities between 1975 and 2004. Over this thirty year period, 47,556 inventors were identified on 44,394 patents issued to U.S. universities. This study examines university inventors as key actors in the innovation process using network analysis, citation analysis and network visualization to interpret policy changes that impact university inventors over a thirty year time period.

## Related Work
Expanding on the studies of co-author collaboration networks in various scientific journals and scholarly communities, this study examines co-inventor collaboration networks of derived from patents granted to U.S. universities p (Barabási et al., 2002; Börner, Maru, & Goldstone, 2004; Leydesdorff, 2007; Newman, 2001a, 2001b) . Likewise, the use of citation measures to analyze the importance of scientific articles influences this study because this study analyzes the impact of each inventor in the university patent network (Garfield, 1955, 1972, 2004; Jaffe, 2000; Jaffe

& Lerner, 2006; Jaffe, Trajtenberg, & Fogarty, 2000a, 2000b; Leydesdorff & Wagner, 2009). This study is theoretically based in sociological studies of social networks, invisible colleges, and complex networks (Barabási, 2003, 2005; Newman, 2001a, 2001b, 2002, 2003, 2004, 2007; Owen-Smith, Riccaboni, Pammolli, & Powell, 2002; Watts, 2003, 2004; Watts & Strogatz, 1998). Finally, this study employs important developments in data visualization, algorithm formulation, and network analysis for studying large amounts of data. The advances achieved by important scholars in this area influence this study (Börner, Chen, & Boyack, 2003; Börner, Dall'Asta, Ke, & Vespignani, 2005; Boyack, Klavans, & Börner, 2005; Boyack, Wylie, Davidson, & Johnson, 2000).

**Preliminary Results**

As a dynamic system, the number of inventors in the network grew from 2,008 unique inventors in the 1975-1979 time interval to a total of 47,556 for the entire thirty year period. Likewise, inventor productivity increased as the size of the overall network increased as well. The mean number of patents per inventor rose from .06 before 1980 to 2.31 by the end of 2004. Increased patenting seems to actually promote both collaboration and collaborative diversity. Likewise, an increased emphasis on patenting at the university appears to have decreased scientific isolation. Before 1980 isolated inventors represented 19% of the network. By the end of 2004, isolated and unconnected inventors only represented 5.3% of the network. At the same time, it appears that the impact of technologies created in university laboratories has grown as well when measured as citation strength. Whereas the mean citations per patent per inventor was .576 before 1980, by the end of 1999, that figure had grown to 3.229. This increasing rate of citation strength could be interpreted as a means of knowledge diffusion and that university inventors are contributing substantially to the exchange of ideas through their patenting activities.

**Table 1: Inventor Network Analysis**

| **Time Interval** | **75-79** | **80-84** | **85-89** | **90-94** | **95-99** | **00-04** | **75-04** |
|---|---|---|---|---|---|---|---|
| Network Type | Tree Simple | Tree Simple | Tree Simple | Scale-Free Complex | Scale-Free Complex | Scale-Free Complex | Scale-Free Complex |
| Patents | 1674 | 2269 | 4118 | 7474 | 12978 | 15881 | 44394 |
| Nodes | 2008 | 2954 | 5662 | 10273 | 18108 | 23501 | 47556 |
| Isolates | 385<br>19.1% | 498<br>16.8% | 808<br>14.3% | 1072<br>10.4% | 1224<br>6.7% | 1277<br>5.4% | 3317<br>7% |
| Edges | 1611 | 2524 | 5467 | 11724 | 26151 | 38761 | 75464 |
| Average Degree ⟨k⟩ | 1.604 | 1.709 | 1.931 | 2.282 | 2.888 | 3.299 | 3.174 |
| ASP | 1.455 | 1.825 | 1.841 | 3.151 | 7.209 | 8.628 | 13.373 |
| Diameter | 5 | 8 | 9 | 15 | 26 | 23 | 44 |
| Density | .0008 | .00058 | .00034 | .00022 | .00016 | .00014 | .00007 |
| Watts-Strogatz Clustering | .885 | .903 | .894 | .885 | .891 | .891 | .844 |
| Connected Components | 934 | 1308 | 2322 | 3589 | 5121 | 5752 | 10565 |
| Largest Component | 20<br>1% | 37<br>1.2% | 49<br>.9% | 147<br>1.4% | 488<br>2.7% | 948<br>4.0% | 12111<br>25.5% |
| PL Exponent | 2.961 | 2.807 | 2.648 | 3.031 | 2.858 | 2.821 | 2.842 |
| Beta Index | .802 | .854 | .965 | 1.141 | 1.444 | 1.649 | 1.587 |

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